Hydrologic Modeling for Ecosystem Restoration, Lockport Prairie, Illinois

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Abstract

Lockport Prairie Nature Preserve, located about 45 miles from Chicago along the Des Plaines River, is one of the few remaining protected natural areas along the river that represents pre-settlement conditions of a dolomite prairie community. The site is home to several Federally and State-listed endangered species. A Section 206 Aquatic Ecosystem Restoration Project seeks to restore and rewet approximately 300 acres of degraded wetland and associated aquatic ecosystems, as well as breeding habitat for the federally threatened *Somatochlora hineana*, the Hine's Emerald Dragonfly, and habitat for the federally endangered *Dalea foliosa*, the Leafy Prairie Clover, along with numerous state listed species.

Groundwater seepage from steep rock outcroppings west of the prairie and from highly fractured bedrock exposed throughout the prairie contributes to prairie surface water. The presence of these seepage zones creates habitat for the prairie's rare species.

As part of the project feasibility study, both groundwater and surface water data are being collected for two years. Groundwater monitoring continues at six well nest locations, while surface water flows through culverts, rivulets and French drains were measured at 10 locations within the prairie. An HEC-HMS model is being developed using the Soil Moisture Accounting loss method. Because of the importance of groundwater to the prairie ecosystem, a groundwater model will also be developed. This paper provides an overview of the project, describes data collection efforts and GIS usage, and discusses hydrologic model development and the challenge of integrating surface water and groundwater modeling results.

Project Overview

Lockport Prairie is located in Will County, Illinois, along the Des Plaines River, approximately 45 miles southwest of Chicago. (Figure 1) The site is approximately 365 acres in size, and 249 acres were dedicated in 1983 as Illinois State Nature Preserve. Lockport Prairie is one of the few remaining protected natural areas along

the Des Plaines River that represents near pre-settlement conditions of a dolomite prairie community.

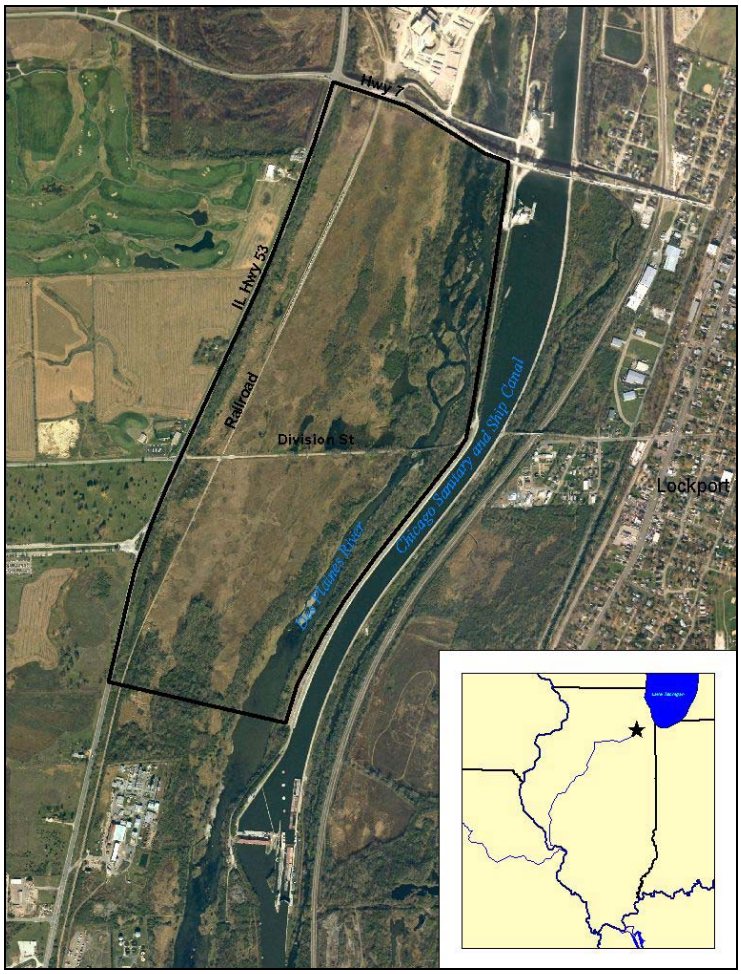

Figure 1. Lockport Prairie, Illinois

Lockport Prairie was carved out during the last glacier retreat nearly 12,000 years ago. The glacial meltwater that formed the Des Plaines River Valley exposed dolomite bedrock along the valley floor. Lockport Prairie is located on the rocky terraces of this flat valley floor. The Des Plaines River borders Lockport Prairie to the east, and steep rock outcroppings form the western border of the site. Groundwater discharges from seeps along the western bluff. The bedrock underlying the site is highly fractured and readily conducts water through open fractures in the upper layers. The presence of seepage zones creates habitat for the prairie's rare species.

Nearly 400 native plant species have been identified at Lockport Prairie, including numerous rare species. Six Federally and/or State-listed endangered plant and animal species live on the prairie. Of the listed species, the Hine's Emerald Dragonfly (*Somatochlora hineana*) breeds in the rivulets formed by consolidating fen and spring

waters, and hunts along the western bluff. The Lakeside Daisy (*Actinea herbacea*) was reintroduced to the site as part of a recovery plan and is reproducing there. The Leafy Prairie Clover (*Dalea foliosa*) was considered locally extinct until its 1974 discovery at Lockport Prairie. The State endangered Spotted Turtle (*Clemmys guttata*) is only found in Illinois in Will County. (USACE 2002)

Although Lockport Prairie contains some of the last remaining high quality dolomite prairie in Illinois, a number of factors appear to be degrading it. Flow in a set of seeps and rivulets has been reduced or eliminated in the last several years. The reduction or disappearance of flow in the seeps and rivulets poses a potentially serious threat to the Hine's Emerald Dragonfly. Alterations in surface flow patterns resulting from the historical construction of both Division Street through the middle of the prairie and the railroad tracks along the western side of the prairie and from recent changes in groundwater discharge to the site may be negatively impacting the prairie species. Fire suppression and possibly hydrologic modifications have resulted in the prairie being invaded by woody, non-native species. These changes in the site hydrology may be contributing to the decline of the Hine's Emerald Dragonfly and Leafy Prairie Clover over the past five years.

The Chicago District Corps of Engineers and the Forest Preserve District of Will County, the local sponsor, initiated a Section 206 Aquatic Ecosystem Restoration feasibility study in 2002. The Lockport Prairie Project seeks to restore and rewet the degraded wetland and associated aquatic ecosystems, as well as restore breeding habitat for the Hine's Emerald Dragonfly and the Leafy Prairie Clover.

Site Hydrology

Average annual rainfall for Lockport Prairie is 37.5 inches, based on 1992 to 2001 daily data collected at the Romeoville-Lewis University gage located just over one-half mile northwest of the site.

Surface water flow patterns for the site are generally from west to east, from the offsite areas to the Des Plaines River. Precipitation falling on the offsite areas is conveyed across Route 53 where it joins with groundwater seepage from the western bluff. This flow then passes through five culvert crossings and three french drains beneath the railroad. Surface water then flows through the prairie through a series of small rivulets and ponds that discharge to the Des Plaines River. Figure 2 shows the locations of the culverts, french drains, and rivulets.

A digital terrain model for Lockport Prairie was developed from a one-foot contour map of the site. The DTM was converted to a digital elevation model that was used to delineate the Lockport Prairie sub-basins shown in Figure 2.

Groundwater flow is generally from northwest to southeast, out of the western bluff and towards the Des Plaines River. A band of sand and gravel extends north to south directly adjacent to the bluff. Groundwater can move freely through the interface of

this band and the underlying dolomite bedrock. It is likely that groundwater up-wells through fractures in the dolomite prairie. Figure 3 shows a groundwater cross-section of Lockport Prairie.

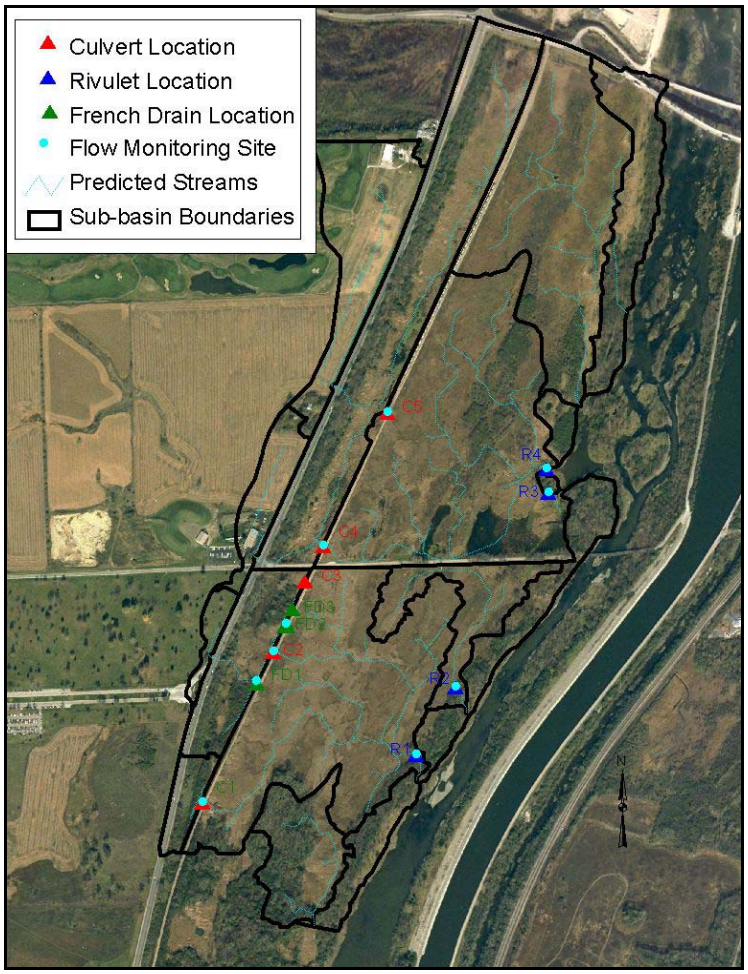

Figure 2. Lockport Prairie Sub-basins with Culvert, French Drain and Rivulet Locations

Surface water flow, groundwater and rainfall data collection at Lockport Prairie was initiated in order to describe and quantify the site hydrology. The connection between the hydrologic processes and the functioning of the ecosystem at Lockport Prairie needs to be better understood before a final ecosystem restoration plan can be selected.

Surface Water Flow Data Collection

A simple water budget for site inflows, outflows and losses indicated that monitoring equipment would need to measure very low surface water flows for use in calibrating a continuous period hydrologic model. V-notch box weir culverts were used to

measure flows through the culverts, two of the rivulets and immediately upstream of the french drains. A 60-degree V-notch weir was selected as the control section, instead of a broad-crested or rectangular weir, to give a greater degree of accuracy for low flows. In the remaining two rivulets, a pipe was installed that would allow calculation of flow based on the velocity and area of the discharge through the pipe. Flow sensors, connected to a battery-operated recording unit, were installed upstream of the control sections to measure depths and velocities. Example flow monitoring equipment installations are shown in Figures 4 and 5. (GAS 2002a)

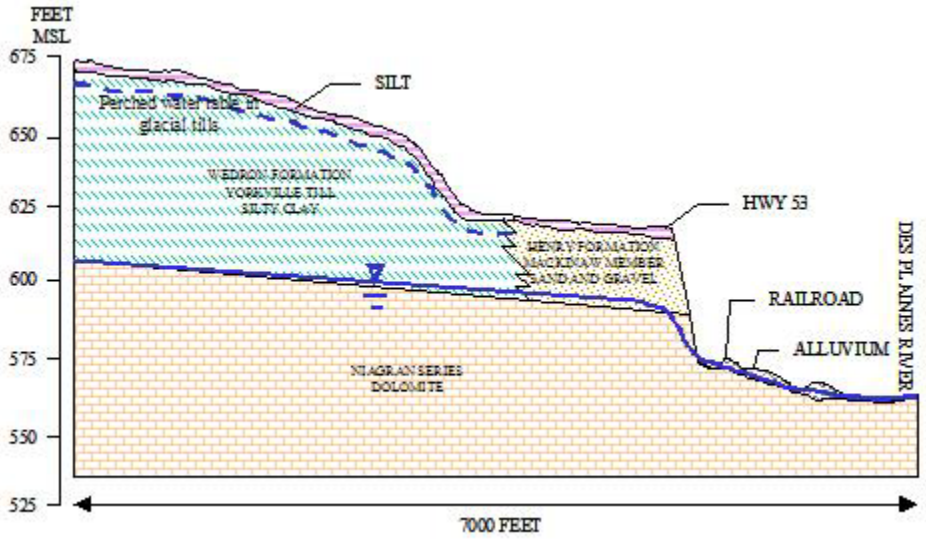

Figure 3. Groundwater Cross-Section of Lockport Prairie *(After GAS 2002b, printed with permission from GAS)*

Surface water flow was monitored at 10 locations within Lockport Prairie: culverts 1, 2, 4 and 5; french drains 2 and 3; and rivulets 1 through 4. Culvert 3 was not selected for monitoring because field investigations found it to be full of sediment. Flows were monitored at all but the french drains from August to December 2001 and from April to November 2002. The french drain flow was measured from May to November 2002. The surface water flow monitoring will continue in the 2003.

The culvert flows and french drain flows reflect inflows to the inner sub-basins at Lockport Prairie, while measured rivulet flows indicate outflows from these sub-basins. Average daily flows at each of the monitored locations for the two monitoring periods are shown in Table 1. The range of average daily flows is large. For example, culvert 4 flows exceeded 2000 cubic feet per day for 16 days in May 2002 and went to 0 (zero) cubic feet per day in early September 2002. (GAS 2002c)

The differences in average daily flows measured in 2001 versus 2002 might be explained by the differences in rainfall during the monitoring periods. Total rainfall in 2001 was just slightly above average, while 2002 was a dry year. The average total rainfall for the months September through November is 9.0 inches, as measured at the Romeoville-Lewis University gage. In 2001, the total rainfall measured from an

onsite rain gage during these months was 10.3 inches. In 2002, the total rainfall measured at Lockport Prairie for the months May through October was 15.8 inches. The average total rainfall for this same time period is 22.5 inches. For the most part, the flows at the 10 monitoring locations reflect the below average precipitation in 2002 when compared to 2001 flows; however, rivulets 3 and 4 show substantially increased flow during 2002. The reason for this discrepancy is not known.

Figure 4. V-Notch Weir Installation at Culvert 4, August 2002

Figure 5. Pipe Installation at Rivulet 2, August 2002

Table 1. Average Daily Surface Flows at Monitoring Locations (cubic feet/day)

Location	Aug – Dec 2001	Apr – Nov 2002
Culvert 1	16	85
Culvert 2	150	21
Culvert 4	2487	750
Culvert 5	15	50
Rivulet 1	603	537
Rivulet 2	323	227
Rivulet 3	147	387
Rivulet 4	381	936
French Drain 2	Data not collected	9
French Drain 3	Data not collected	9

Groundwater Data Collection

There are three regional aquifers in Will County. These are the deep sandstone aquifer, the dolomite aquifer and the shallow sand and gravel glacial aquifer. In terms of yield and use, the two most important aquifers are the deep sandstone aquifer and the dolomite aquifer, which are capable of sustaining high capacity wells. Demand pressure on the dolomite aquifer and the sand and gravel aquifer (together, commonly referred to as the "shallow aquifer") has been increasing in recent years due to over use and water quality issues within the sandstone aquifer, where radium concentrations can locally be high.

A hydrogeological assessment was determined necessary to better understand how groundwater enters the site, to identify off-site activities that may impact supply, and to estimate the contribution of groundwater to the water budget for the site. Past evidence of groundwater seeps along the bluff bordering Lockport Prairie is an indication that the groundwater component of the water budget may be a significant factor in providing life-sustaining water to this unique ecosystem.

To address a lack of site-specific information for Lockport Prairie, six monitoring well nests and 23 shallow well points were installed in 2001. The monitoring of the groundwater continues.

The well nests were installed inside and outside Lockport Prairie. Initially, nine well nests were planned; however, due to access denial and right-of-way utility corridor complications, well nests 1, 2 and 4 have not been installed. Well nests 6, 7, 8 and 9 were installed in June 2001, while well nests 3 and 5 were completed in November 2001. The locations of the well nests are shown in Figure 6.

Each well nest consists of two to four individual wells installed at varying depths below ground surface. Data logging pressure transducers were installed in well nests

6, 7 and 8 in 2001, and reinstalled in well nest 9 after the 2001 growing season. (GAS 2002b)

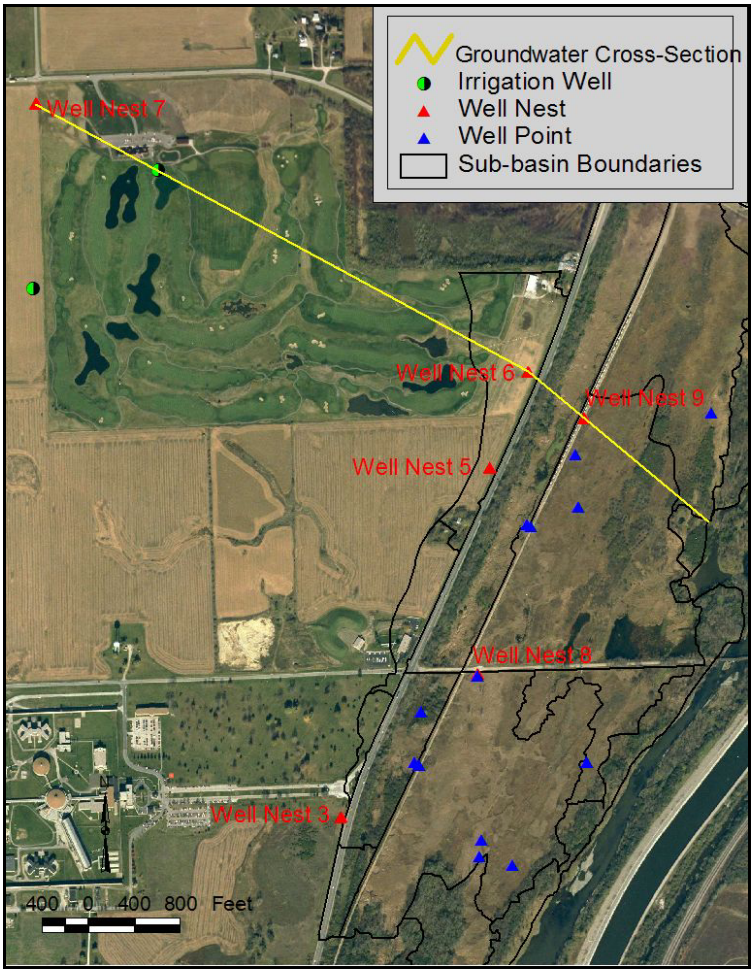

Figure 6. Monitoring Well Nest and Well Point Locations

The lengths of the well points range in depth from two to five feet. Water levels in the points are measured by hand using an electronic water level tape.

To aid in determining what off-site activities may be impacting the groundwater supply, a well search of the suspected recharge zone for the prairie has been undertaken to evaluate the size and distribution of groundwater sinks.

Hydrologic Model

In order to assess existing conditions at Lockport Prairie and to predict how future changes to the hydrology may influence the water balance and dependent ecosystems, a hydrologic model is being developed. Recently, a surface water model was

calibrated using data collected at Lockport Prairie. The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) is being used as the surface water model for the project. Currently, the type of groundwater model to be used at Lockport Prairie is being evaluated. One issue impacting the selection of a groundwater model is the need to be able to integrate the groundwater and surface water models. Other factors being considered are data requirements, model accuracy, time constraints, and total cost of the modeling effort.

Eleven sub-basins are included in the HEC-HMS model. The easternmost sub-basins shown in Figure 2 are not included in the HEC-HMS model.

The HEC-HMS Soil Moisture Accounting (SMA) loss method is being used since it allows the analysis of the watershed's response to continuous precipitation records, including periods with and without rainfall. Because it accounts for changes in the soil moisture between precipitation events, the SMA method allows the evaluation of the impact of both wet and dry periods on the Lockport Prairie ecosystem.

The SMA method simulates the movement of water through and storage of water on vegetation, on the soil surface, in the soil profile, and in groundwater layers. SMA represents the watershed as a series of storage layers: (1) canopy interception, (2) surface depression, (3) tension zone and upper zone (soil profile) and (4) groundwater.

Canopy layer storage capacity was initially selected from suggested literature values for short prairie grasses and woody vegetation. The estimated canopy storage for each sub-basin of the HEC-HMS model east of the railroad initially ranged from 0.08 to 0.12 inches. During calibration the canopy storage was lumped with surface storage, and the calibrated combined values range from 0 (zero) to 0.044 inches. The calibrated values indicate an overestimation of initial storage capacity in the prairie canopy.

Water infiltration rates were measured at Lockport Prairie and ranged from 48 to 2000 centimeters per hour. The mean infiltration rate measured was 535 centimeters per hour. (Simpson 2001) Values in this range were suspected to be too high and were not used as the initial maximum infiltration rates for the sub-basins. Rather, the initial maximum infiltration rates for the sub-basins were determined from typical values associated with identified soil classifications. The calibrated infiltration rates for the sub-basins east of the railroad range from 0.01 to 0.5 inches.

Tension zone capacities and maximum percolation rates in the soil zone were calibrated to values in the range of 0.00015 to 0.16 inches and 0.019 to 0.066 inches per hour, respectively. The need for additional soil data became apparent during the calibration of the surface water model. Currently, the project team is working with Natural Resources Conservation Service soil scientists to determine data needs and methods for collecting additional data at Lockport Prairie.

Only one groundwater layer is used in the HEC-HMS model for Lockport Prairie. (Two groundwater layers are available in the SMA method.) This simplified the calibration procedure and better reflects the actual geology of the site. The calibrated groundwater storage capacity for each sub-basin is between 0.03 and 2.0 inches, and the storage coefficient is between 0.1 and 105 hours. The latter variation is expected to decrease when additional calibration data becomes available.

The linear-reservoir baseflow model is used in conjunction with the SMA method in HEC-HMS. The model uses outflow from the groundwater layer to determine baseflow for the watershed.

The Clark unit hydrograph method was selected to transform precipitation into surface water flow for Lockport Prairie. Although the kinematic wave method was tried during calibration, the Clark method better matches the measured hydrographs.

The HEC-HMS model was calibrated to the 2002 surface water flow data. Due to the limited 2001 data collection time period and the difference in rainfall between the two monitoring years, it was determined that only the 2002 data be used for calibration. A second full growing season of surface water flow data will be collected in 2003. The data will be used to further refine the surface water model calibration.

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